

INTERNATIONAL STANDARD

NORME INTERNATIONALE



GROUP SAFETY PUBLICATION
PUBLICATION GROUPÉE DE SÉCURITÉ

Safety requirements for power electronic converter systems and equipment – Part 1: General

**Exigences de sécurité applicables aux systèmes et matériels électroniques de
conversion de puissance –
Partie 1: Généralités**



THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC

Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Recherche de publications IEC - webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études, ...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



IEC 62477-1

Edition 2.0 2022-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE



GROUP SAFETY PUBLICATION
PUBLICATION GROUPÉE DE SÉCURITÉ

Safety requirements for power electronic converter systems and equipment – Part 1: General

Exigences de sécurité applicables aux systèmes et matériels électroniques de conversion de puissance – Partie 1: Généralités

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 29.200

ISBN 978-2-8322-2199-0

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	11
INTRODUCTION.....	14
1 Scope.....	16
2 Normative references	17
3 Terms and definitions	20
4 Protection against hazards	33
4.1 General.....	33
4.2 <i>Single fault conditions</i> and <i>abnormal operating conditions</i>	33
4.3 Short-circuit and overload protection.....	34
4.3.1 General	34
4.3.2 Input short-circuit withstand strength and <i>output short-circuit current</i> ability.....	36
4.3.3 Short-circuit coordination (backup protection)	37
4.3.4 Protection by several devices	37
4.4 Protection against electric shock.....	37
4.4.1 General	37
4.4.2 <i>Decisive voltage class</i>	40
4.4.3 Means for <i>basic protection</i> (protection against direct contact)	44
4.4.4 Means for <i>fault protection</i> (protection against indirect contact)	45
4.4.5 Means for <i>enhanced protection</i>	55
4.4.6 Protective means for equipment classes	56
4.4.7 <i>Insulation</i>	58
4.4.8 Compatibility with residual current-operated protective devices (RCD).....	75
4.4.9 Capacitor discharge.....	76
4.5 Protection against electrical energy hazards	76
4.5.1 <i>General access areas</i>	76
4.5.2 <i>Service access areas</i>	77
4.6 Protection against fire and thermal hazards	77
4.6.1 Circuits representing a fire hazard	77
4.6.2 <i>Components</i> representing a fire hazard	77
4.6.3 <i>Fire enclosures</i>	79
4.6.4 Temperature limits	83
4.6.5 Limited power sources	86
4.7 Protection against mechanical hazards	87
4.7.1 General	87
4.7.2 Specific requirements for liquid cooled <i>PECS</i>	88
4.7.3 Mechanical hazards from rotating parts	89
4.7.4 Sharp edges	90
4.8 <i>PECS</i> with multiple sources of supply	90
4.9 Protection against environmental stresses	91
4.10 Protection against excessive acoustic noise hazards	92
4.11 Wiring and connections.....	93
4.11.1 General	93
4.11.2 <i>Insulation</i> of conductors.....	93
4.11.3 Stranded wire	95
4.11.4 Routing and clamping	95
4.11.5 Identification of conductors and terminals	95

4.11.6	Splices and connections	96
4.11.7	<i>Accessible connections</i>	96
4.11.8	Interconnections between parts of the <i>PECS</i>	97
4.11.9	Supply connections.....	97
4.11.10	<i>Field wiring terminals</i> and internal terminals	99
4.11.11	Means for shield connection of shielded wire or shielded cable	101
4.12	<i>Enclosures</i>	101
4.12.1	General	101
4.12.2	Handles and manual controls.....	102
4.12.3	Cast metal	102
4.12.4	Sheet metal	103
4.12.5	Stability requirement for <i>enclosure</i>	105
4.12.6	Strain relief.....	106
4.12.7	Polymeric <i>enclosure</i> stress relief	106
4.12.8	Polymeric <i>enclosure</i> UV resistance.....	106
4.13	<i>Components</i>	106
4.13.1	General	106
4.13.2	PTC thermistors.....	107
4.13.3	<i>Mains supply cords</i>	107
4.13.4	Capacitors and RC units bridging <i>insulation</i>	107
4.13.5	Wound components	107
4.13.6	Plug and socket-outlets	108
4.14	Protection against electromagnetic fields	108
5	Test requirements.....	108
5.1	General.....	108
5.1.1	Test objectives and classification.....	108
5.1.2	Selection of test samples	108
5.1.3	Sequence of tests	108
5.1.4	Earthing conditions	109
5.1.5	General conditions for tests	109
5.1.6	Compliance	110
5.1.7	Test overview	110
5.2	Test specifications	112
5.2.1	<i>Visual inspection (type test and routine test)</i>	112
5.2.2	Mechanical tests.....	112
5.2.3	Electrical tests	121
5.2.4	<i>Abnormal operation</i> and simulated faults tests	141
5.2.5	Material tests	148
5.2.6	Environmental tests (<i>type tests</i>).....	153
5.2.7	Hydrostatic pressure test (<i>type test, routine test</i>).....	157
5.2.8	Electromagnetic fields (EMF).....	158
6	Information and marking requirements.....	158
6.1	General.....	158
6.2	Information for selection	160
6.2.1	General	160
6.2.2	Instructions and markings pertaining to <i>accessories</i>	162
6.3	Information for installation and commissioning	162
6.3.1	General	162
6.3.2	Mechanical considerations.....	162

6.3.3	Environment	162
6.3.4	Handling and mounting	162
6.3.5	<i>Enclosure</i> temperature	163
6.3.6	<i>Open type PECS</i>	163
6.3.7	Connections	163
6.3.8	Commissioning	165
6.3.9	Protection requirements	165
6.4	Information for intended use	167
6.4.1	General	167
6.4.2	Adjustment	167
6.4.3	Labels, signs, symbols and signals	168
6.4.4	Hot surfaces	170
6.4.5	Control and device marking	170
6.5	Supplementary information	170
6.5.1	Maintenance	170
6.5.2	Capacitor discharge	171
6.5.3	Auto restart/bypass connection	171
6.5.4	Other hazards	171
6.5.5	<i>PECS</i> with multiple sources of supply	171
6.5.6	Replaceable fuses in neutral of single-phase <i>PECS</i>	171
Annex A (normative)	Additional information for protection against electric shock	173
A.1	General	173
A.2	Protection by means of <i>DVC As</i>	173
A.3	Protection by means of <i>protective impedance</i>	173
A.4	Protection by using limited voltages	174
A.5	Evaluation of the <i>working voltage</i> of circuits	175
A.5.1	General	175
A.5.2	Classification of the <i>working voltage</i>	175
A.5.3	<i>AC working voltage</i>	176
A.5.4	<i>DC working voltage</i>	176
A.5.5	<i>Pulsating working voltage</i>	177
A.6	The concept of protective means according to 4.4	178
A.6.1	General	178
A.6.2	Examples of the use of elements of protective means	178
Annex B (informative)	Considerations for the reduction of the <i>pollution degree</i>	180
B.1	General	180
B.2	Factors influencing the <i>pollution degree</i>	180
B.3	Reduction of influencing factors	180
Annex C (informative)	Symbols referred to in this document	181
C.1	Symbols used	181
C.2	Determination of contrast	182
Annex D (normative)	Evaluation of <i>clearance</i> and <i>creepage distances</i>	184
D.1	Measurement	184
D.2	Relationship of measurement to <i>pollution degree</i>	184
D.3	Examples	185
Annex E (normative)	Altitude correction for <i>clearances</i>	191
E.1	Correction factor for <i>clearances</i> at altitudes above 2 000 m	191
E.2	Test voltages for verifying <i>clearances</i> at different altitudes	191

Annex F (normative) <i>Clearance</i> and <i>creepage distance</i> determination for frequencies greater than 30 kHz	193
F.1 General influence of the frequency on the withstand characteristics	193
F.2 <i>Clearance</i>	193
F.2.1 General	193
F.2.2 <i>Clearance</i> for inhomogenous fields	194
F.2.3 <i>Clearance</i> for approximately homogenous fields	195
F.3 <i>Creepage distance</i>	196
F.4 <i>Solid insulation</i>	197
F.4.1 General	197
F.4.2 Approximately uniform field distribution without air gaps or voids	197
F.4.3 Other cases	198
Annex G (informative) Cross-sections of round conductors	199
Annex H (informative) Guidelines for RCD compatibility	200
H.1 Selection of RCD type	200
H.2 Fault current waveforms	201
Annex I (informative) Examples of <i>overvoltage category</i> reduction	204
I.1 General	204
I.2 Protection to the surroundings (see 4.4.7.2)	204
I.2.1 Circuits connected to <i>mains supply</i> (see 4.4.7.2.3)	204
I.2.2 Circuits connected to the <i>non-mains supply</i> (see 4.4.7.2.4)	207
I.2.3 Protection between circuits (see 4.4.7.2.7)	207
I.3 <i>Functional insulation</i> (see 4.4.7.3)	208
I.4 Further examples	208
I.5 Circuits with multiple supplies (see 4.4.7.2.1)	209
Annex J (informative) Burn thresholds for touchable surfaces	210
J.1 General	210
J.2 Burn thresholds	210
Annex K (informative) Table of electrochemical potentials	214
Annex L (informative) Measuring instrument for <i>touch current</i> measurements	215
L.1 Measuring instrument 1	215
L.2 Measuring instrument 2	215
L.3 Measuring instrument 3	216
Annex M (normative) Test probes for determining access	217
Annex N (informative) Guidance regarding short-circuit current	220
N.1 General	220
N.2 Coordination of short-circuit current	221
N.2.1 General	221
N.2.2 <i>Conditional short-circuit current</i> (I_{CC}) and <i>minimum required prospective short-circuit current</i> ($I_{CP, mr}$)	221
N.2.3 <i>Short-time withstand current</i> (I_{CW})	223
N.3 Guidance for specification of short-circuit current and <i>short-circuit protective device</i>	224
N.3.1 General	224
N.3.2 Example 1: Two or more <i>PECS</i> with different ratings	225
N.3.3 Specification of I_{CC}	226
N.3.4 Specification of I_{CW}	226

N.3.5	Example 2: One <i>PECS</i> with more than one rating	227
N.3.6	Additional explanation on terms, definitions and specifications	228
N.4	Short-circuit rating and <i>single fault conditions</i> testing	229
N.4.1	General	229
N.4.2	Exemption from <i>short-time withstand current</i> testing	231
N.5	Guideline for short-circuit analysis	231
Annex O (informative)	Guidelines for determination of <i>clearance</i> and <i>creepage distances</i>	232
O.1	Guideline for determination of <i>clearances</i>	232
O.2	Guideline for determination of <i>creepage distances</i>	233
O.3	Minimum spacings within <i>solid insulation</i> or similar	233
Annex P (informative)	Protection of persons against electromagnetic fields for frequencies from 0 Hz up to 300 GHz	235
P.1	General influence of electromagnetic fields to persons	235
P.1.1	General	235
P.1.2	Low-frequency electric fields effects (1 Hz to 100 kHz)	235
P.1.3	Low-frequency magnetic fields effects (1 Hz to 100 kHz)	235
P.1.4	Low-frequency electric and magnetic fields effects	235
P.1.5	High-frequency electromagnetic fields effects (100 kHz to 300 GHz)	235
P.1.6	Current knowledge on low-level effects	236
P.1.7	Biological effects versus adverse health effects	236
P.1.8	Influence of EMF on passive and active medical implants	236
P.2	Requirements from ICNIRP LF guidelines against exposure to EMF	236
P.2.1	Adoption of exposure limits from ICNIRP	236
P.2.2	Limits of EMF exposure for transportation and storage	238
P.3	Protection of persons against exposure of EMF	238
P.3.1	General	238
P.3.2	EMF requirements for general public access areas	239
P.3.3	EMF requirements for <i>general access areas</i> , <i>service access areas</i> and <i>restricted access areas</i>	239
P.3.4	EMF requirements for transportation and storage	239
P.4	Electromagnetic fields (EMF) test (<i>type test</i>)	240
P.4.1	General test set up for EMF	240
P.4.2	EMF test (<i>type test</i>)	240
P.5	Electromagnetic fields (EMF) marking	240
Annex Q (informative)	Maximum disconnection times	241
Annex R (informative)	Risk assessment according to IEC Guide 116	242
R.1	General	242
R.2	Risk assessment	242
Annex S (informative)	Guidance to product technical committees	244
Bibliography		245
Figure 1 – Protective means for protection against electric shock considering <i>Class I equipment</i> and <i>Class II equipment</i>		39
Figure 2 – Protective means for protection against electric shock considering <i>Class III equipment</i> or <i>accessible circuits</i> of <i>DVC As</i>		40
Figure 3 – Example of a <i>PECS</i> assembly and its associated <i>protective equipotential bonding</i>		47

Figure 4 – Example of a <i>PECS</i> assembly and its associated <i>protective equipotential bonding</i> through direct metallic contact.....	48
Figure 5 – Time-voltage zones for <i>accessible circuits</i> of <i>DVC As</i> and <i>DVC B</i> – DC during <i>single fault conditions</i>	52
Figure 6 – Time-voltage zones for <i>accessible circuits</i> of <i>DVC As</i> and <i>DVC B</i> – AC peak during <i>single fault conditions</i>	53
Figure 7 – Time-voltage zones for conductive <i>accessible parts</i> during <i>single fault conditions</i>	54
Figure 8 – <i>Fire enclosure</i> bottom openings below an unenclosed or partially enclosed fire-hazardous <i>component</i>	81
Figure 9 – <i>Fire enclosure</i> baffle construction.....	82
Figure 10 – Example for interconnections within <i>permanently connected PECS</i> and between parts of them	93
Figure 11 – Example of cable as an arrangement of insulated conductors.....	94
Figure 12 – Detachable <i>mains supply</i> cords and connections.....	98
Figure 13 – Example for evaluation of wire bending space	101
Figure 14 – Supported and unsupported <i>enclosure</i> parts	103
Figure 15 – Impact test using a steel ball	118
Figure 16 – Voltage test procedures	127
Figure 17 – Partial discharge test procedure.....	129
Figure 18 – <i>Protective equipotential bonding</i> impedance test for separate <i>PECS</i> with power fed from the <i>PECS</i> with protection for the power cable	134
Figure 19 – <i>Protective equipotential bonding</i> impedance test for sub-assembly with <i>accessible parts</i> and with power fed from the <i>PECS</i>	135
Figure 20 – Electric strength test instrument	138
Figure 21 – Mandrel.....	139
Figure 22 – Initial position of mandrel	139
Figure 23 – Final position of mandrel	139
Figure 24 – Position of metal foil on insulating material.....	140
Figure 25 – Circuit for high-current arcing test	148
Figure 26 – Test fixture for hot-wire ignition test	150
Figure A.1 – Protection by <i>DVC As</i> with <i>enhanced protection</i>	173
Figure A.2 – Protection by means of <i>protective impedance</i>	174
Figure A.3 – Protection by using limited voltages	174
Figure A.4 – Typical waveform for <i>AC working voltage</i>	176
Figure A.5 – Typical waveform for <i>DC working voltage</i>	176
Figure A.6 – Typical waveform for pulsating <i>working voltage</i>	177
Figure D.1 – Example of measurements including a groove	185
Figure D.2 – Example of measurements including a groove	185
Figure D.3 – Example of measurements including a groove	185
Figure D.4 – Example of measurements including a rib.....	186
Figure D.5 – Example of measurements providing protection of type 2.....	186
Figure D.6 – Example of measurements providing protection of type 1.....	186
Figure D.7 – Example of measurements providing protection of type 1.....	187
Figure D.8 – Example of measurements providing protection of type 1.....	187
Figure D.9 – Example of measurements including a barrier (cemented joint).....	187

Figure D.10 – Example of measurements including a barrier	188
Figure D.11 – Example of measurements including a gap	188
Figure D.12 – Example of measurements including a gap	189
Figure D.13 – Example of measurements including an isolated conductive part	189
Figure D.14 – Example of measurements in inner layer of PWB	189
Figure D.15 – Example of measurements on <i>enclosure</i> of insulating material to a part inside.....	190
Figure F.1 – Diagram for dimensioning of <i>clearances</i>	194
Figure F.2 – Diagram for dimensioning of <i>creepage distances</i>	196
Figure F.3 – Permissible field strength for dimensioning of <i>solid insulation</i> according to Formula (F.1).....	198
Figure H.1 – Flow chart leading to selection of the RCD type upstream of a <i>PECS</i>	200
Figure H.2 – Symbols for marking depending on the type of RCD	201
Figure H.3 – Fault current waveforms in connections with <i>power electronic converter</i> devices	203
Figure I.1 – <i>Basic protection</i> evaluation for circuits connected to the origin of the <i>installation mains supply</i>	204
Figure I.2 – <i>Basic protection</i> evaluation for circuits connected to the <i>mains supply</i>	205
Figure I.3 – <i>Basic protection</i> evaluation for single and three phase <i>PECS</i> not <i>permanently connected</i> to the <i>mains supply</i>	205
Figure I.4 – <i>Basic protection</i> evaluation for circuits connected to the origin of the <i>installation mains supply</i> where internal <i>SPDs</i> are used.....	205
Figure I.5 – <i>Basic protection</i> evaluation for circuits connected to the <i>mains supply</i> where internal <i>SPDs</i> are used.....	206
Figure I.6 – Example of <i>enhanced protection</i> evaluation for circuits connected to the <i>mains supply</i> where internal <i>SPDs</i> are used	206
Figure I.7 – Example of <i>enhanced protection</i> evaluation for circuits connected to the <i>mains supply</i> where internal <i>SPDs</i> are used	206
Figure I.8 –Example of <i>enhanced protection</i> evaluation for circuits connected to the <i>mains supply</i> where internal <i>SPDs</i> are used	207
Figure I.9 – <i>Basic protection</i> evaluation for circuits connected to the <i>non-mains supply</i>	207
Figure I.10 – <i>Basic protection</i> evaluation for circuits connected to the origin of the <i>installation non-mains supply</i>	207
Figure I.11 – <i>Functional insulation</i> evaluation within circuits affected by external transients.....	208
Figure I.12 – <i>Basic protection</i> evaluation for circuits connected to the <i>mains supply</i>	208
Figure I.13 – <i>Insulation</i> evaluation for <i>accessible circuit</i> of <i>DVC As</i>	208
Figure I.14 – <i>PEC</i> with <i>mains supply</i> and <i>non-mains supply</i> without galvanic isolation	209
Figure I.15 – Transformer (basic protected) <i>PEC</i> inverter with <i>SPD</i> and transformer to reduce impulse voltage for functional and <i>basic protection</i>	209
Figure J.1 – Burn threshold spread when the skin is in contact with a hot smooth surface made of bare (uncoated) metal.....	210
Figure J.2 – Rise in the burn threshold spread from Figure J.1 for metals which are coated by shellac varnish.....	211
Figure J.3 – Rise in the burn threshold spread from Figure J.1 for metals coated with the specific materials	211
Figure J.4 – Burn threshold spread when the skin is in contact with a hot smooth surface made of ceramics, glass and stone materials	212

Figure J.5 – Burn threshold spread when the skin is in contact with a hot smooth surface made of plastics	213
Figure L.1 – Measuring instrument 1	215
Figure L.2 – Measuring instrument 2	215
Figure M.1 – Sphere 50 mm probe according to IEC 61032:1997, test probe A	217
Figure M.2 – Jointed test finger according to IEC 61032:1997, test probe B	218
Figure M.3 – Test rod 2,5 mm according to IEC 61032:1997, test probe C	219
Figure M.4 – Sphere 12,5 mm test probe according to IEC 61032:1997, test probe 2	219
Figure N.1 – Example of short-circuit current curve under specification of I_{CC}	222
Figure N.2 – Example of tripping characteristic of a circuit breaker	223
Figure N.3 – Example of tripping characteristic of a current-limiting fuse	223
Figure N.4 – Example of short-circuit current curve under specification of I_{CW}	224
Figure N.5 – Two PECS with different specifications	225
Figure N.6 – One PECS with different specification for each input <i>mains supply port</i>	227
Figure N.7 – Flowchart for classification of I_{CC} or I_{CW}	230
Figure O.1 – Flowchart for determination of <i>clearance</i>	232
Figure O.2 – Flowchart for determination of <i>creepage distance</i>	233
Table 1 – Alphabetical list of terms	20
Table 2 – Voltage limits for the <i>decisive voltage classes DVC</i>	42
Table 3 – Minimum protection requirements for circuit under consideration	43
Table 4 – <i>PE conductor</i> cross-sectional area	49
Table 5 – Limits for access of <i>touch current</i>	56
Table 6 – Definitions of <i>pollution degrees</i>	59
Table 7 – <i>Impulse withstand voltage</i> and <i>temporary overvoltage</i> versus <i>system voltage</i>	61
Table 8 – <i>Clearances</i> for <i>functional insulation</i> , <i>basic insulation</i> or <i>supplementary insulation</i> for inhomogeneous fields	66
Table 9 – <i>Creepage distances</i>	69
Table 10 – Generic materials for the direct support of uninsulated <i>live parts</i>	71
Table 11 – Thin sheet material thickness through <i>insulation</i> requirements	72
Table 12 – Flammability classes and classification standards	78
Table 13 – Permitted openings in <i>fire enclosure</i> bottoms	82
Table 14 – Maximum measured temperatures for internal materials and <i>components</i>	84
Table 15 – Maximum measured temperatures for <i>accessible parts</i> of the PECS	86
Table 16 – Limits for sources without an <i>overcurrent protective device</i>	87
Table 17 – Limits for power sources with an <i>overcurrent protective device</i>	87
Table 18 – Environmental service conditions	92
Table 19 – Wire bending space from terminals to <i>enclosure</i>	100
Table 20 – Thickness of sheet metal for <i>enclosures</i> : carbon steel or stainless steel	104
Table 21 – Thickness of sheet metal for <i>enclosures</i> : aluminium, copper or brass	105
Table 22 – Environmental conditions for tests	109
Table 23 – Test overview	110
Table 24 – Pull values for handles and manual control securement	120

Table 25 – Values for physical tests on strain relief of <i>enclosure</i>	120
Table 26 – <i>Impulse withstand voltage</i> test procedure	122
Table 27 – <i>Impulse withstand voltage test</i>	123
Table 28 – AC or DC test voltage for circuits connected directly to <i>mains supply</i>	125
Table 29 – AC or DC test voltage for circuits connected to <i>non-mains supply</i> without <i>temporary overvoltages</i>	125
Table 30 – Partial discharge test.....	129
Table 31 – Test duration for <i>protective equipotential bonding</i> test.....	136
Table 32 – AC <i>short-time withstand current</i> test, minimum <i>PECS</i> requirements	145
Table 33 – Environmental tests	153
Table 34 – Dry heat test (steady state)	154
Table 35 – Damp heat test (steady state).....	155
Table 36 – Vibration test	156
Table 37 – Salt mist test	156
Table 38 – Dust test.....	157
Table 39 – Sand test.....	157
Table 40 – Marking location	159
Table A.1 – Examples for protection against electric shock	179
Table C.1 – Symbols used	181
Table D.1 – Width of grooves by <i>pollution degree</i>	184
Table E.1 – Correction factor for <i>clearances</i> at altitudes between 2 000 m and 20 000 m	191
Table E.2 – Test voltages for verifying <i>clearances</i> at different altitudes	192
Table F.1 – Minimum values of <i>clearances</i> in air at atmospheric pressure for inhomogeneous field conditions	195
Table F.2 – Multiplication factors for <i>clearances</i> in air at atmospheric pressure for approximately homogeneous field conditions	195
Table F.3 – Minimum values of <i>creepage distances</i> for different frequency ranges	197
Table G.1 – Standard cross-sections of round conductors.....	199
Table K.1 – Table of electrochemical potentials	214
Table O.1 – Minimum spacings within <i>solid insulation</i> or similar.....	234
Table P.1 – Limits of EMF for general public exposure.....	237
Table P.2 – Limits of EMF for occupational exposure.....	238
Table P.3 – Limits for magnetic flux density of static magnetic fields (2013/35/EU).....	238
Table P.4 – EMF test overview	240
Table 41.1 – Maximum disconnection times	241
Table R.1 – Risk assessment.....	242

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**SAFETY REQUIREMENTS FOR POWER ELECTRONIC
CONVERTER SYSTEMS AND EQUIPMENT –****Part 1: General****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 62477-1 has been prepared by IEC technical committee 22: Power electronic systems and equipment. It is an International Standard.

This document is developed according to the intent of ISO/IEC Guide 51 and IEC Guide 116.

It has the status of a group safety publication in accordance with IEC Guide 104.

This second edition cancels and replaces the first edition published in 2012 and Amendment 1:2016. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) PECS emitting or receiving radio waves added in the Scope;
- b) simplification of the concept of DVC As including the voltage-time-zones;

- c) improved consistency of the concept "protection" versus "insulation" according to IEC 61140;
- d) limits for touch current updated and limits for PE conductor currents added;
- e) thin sheet of tape materials reworked and tests added;
- f) inner layers of multi-layer printed wiring boards added;
- g) mechanical hazards updated;
- h) requirements for enclosures updated;
- i) requirements for wiring and connections updated;
- j) polymeric enclosure requirements updated;
- k) requirements for components added;
- l) several test added (e.g. UV, working voltage, SPD, preconditioning);
- m) information and marking requirements updated;
- n) requirements for the contrast of symbols added;
- o) several annexes updated.

The text of this International Standard is based on the following documents:

Draft	Report on voting
22/355/FDIS	22/356/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

A list of all the parts in the IEC 62477 series, published under the general title *Safety requirements for power electronic converter systems and equipment*, can be found on the IEC website.

In this document, terms in *italic* are defined in Clause 3.

NOTE Due to the requirement in ISO/IEC Directive Part 2, the defined term is in singular. In this document, also the plural is in *italic*.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This document relates to products that include *power electronic converters*, with a rated *system voltage* not exceeding 1 000 V AC or 1 500 V DC. It specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, except functional safety as defined in IEC 61508 (all parts). The objectives of this document are to establish a common terminology and basis for the safety requirements of products that contain *power electronic converters* across several IEC technical committees.

During the update of the document, feedback from technical committees which used the IEC 62477-1 as reference document has been taken into consideration.

Modifications have been made to 4.4.2 and Annex A considering the safe to touch voltage *DVC As* under normal operating conditions and *single fault conditions*. On request from TCs using this document as a reference document, the determination of *DVC As* has been simplified. The determination of *DVC As* in IEC 62477-1:2012 and IEC 62477-1:2012/AMD1:2016 was developed based on IEC TS 60479-1:2005¹ and IEC TR 60479-5:2007 and in details taking different environmental condition, size of body contact area and body reaction into consideration. This change also included time-voltage zones in Annex A for relevant body reactions, environmental conditions and contact area.

NOTE See IEC 60479-1:2018 for further information about effects of current on human beings and livestock.

This document follows the simplified concepts of the basic safety standard IEC 61140:2016, 5.2.6, considering two situations in Table 2 of this document:

- a) dry and large contact areas;
- b) all other cases.

For the temporary increase of voltage during *single fault conditions*, it was decided to use the more simplified approach to limit the voltage to the maximum voltage of *DVC B* which is also used by other committees.

This document has been developed with the intention

- to be used as a reference document for product committees inside TC 22 in the development of product standards for *power electronic converter systems* and equipment,
- to replace IEC 62103² as a product family standard providing minimum requirements for safety aspects of *power electronic converter systems* and equipment in apparatus for which no product standard exists, and

NOTE The scope of IEC 62103 contains reliability and electromagnetic compatibility aspects, which are not covered by this document.

- to be used as a reference document for product committees outside TC 22 in the development of product standards of *power electronic converter systems* and equipment intended renewable energy sources. TC 82, TC 88, TC 105 and TC 114, in particular, have been identified as relevant technical committees at the time of publication.

Technical committees using this document should carefully consider the relevance of each paragraph in this document for the product under consideration and reference, add, replace or modify requirement as relevant. Product specific topics not covered by this document are in the responsibility of the technical committees using this document as reference document.

¹ This publication has been withdrawn.

² This publication has been withdrawn.

This group safety standard will not take precedence over any product specific standard according to IEC Guide 104. IEC Guide 104 provides information about the responsibility of product committees to use group safety standards for the development of their own product standards.

SAFETY REQUIREMENTS FOR POWER ELECTRONIC CONVERTER SYSTEMS AND EQUIPMENT –

Part 1: General

1 Scope

This part of IEC 62477 applies to *power electronic converter systems (PECS)*, any specified *accessories*, and their *components* for *electronic power conversion* and electronic power switching, including the means for their control, protection, monitoring and measurement, such as with the main purpose of converting electric power, with rated system *voltages* not exceeding 1 000 V AC or 1 500 V DC.

This document also applies to *PECS* which intentionally emit or receive radio waves for the purpose of radio communication.

This document can also be used as a reference standard for product committees producing product standards for:

- adjustable speed electric power drive systems (PDS);
- standalone uninterruptible power systems (UPS);
- *low voltage* stabilized DC power supplies;
- bidirectional power converters.

For *PECS* and their specified *accessories* for which no product standard exists, this document provides minimum requirements for safety aspects.

This document has the status of a group safety publication in accordance with IEC Guide 104 for *power electronic converter systems* for solar, wind, tidal, wave, fuel cell or similar energy sources.

According to IEC Guide 104, one of the responsibilities of technical committees is, wherever applicable, to make use of basic safety publications and/or group safety publications in the preparation of their product standards.

Guidance for use of this group safety publication for product committees is given in Annex S.

This document

- establishes a common terminology for safety aspects relating to *PECS*,
- establishes minimum requirements for the coordination of safety aspects of interrelated parts within a *PECS*,
- establishes a common basis for minimum safety requirements for the *PECS* portion of products that contain *PECS*,
- specifies requirements to reduce risks of fire, electric shock, thermal, energy and mechanical hazards, during use and operation and, where specifically stated, during service and maintenance, and
- specifies minimum requirements to reduce risks with respect to *PECS* designed as pluggable and *permanently connected equipment*, whether it consists of a system of interconnected units or independent units, subject to installing, operating and maintaining the *PECS* in the manner prescribed by the manufacturer.